Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles,
Interim Report, NESCCAF, March 2004

Indirect GHG Impacts of Vehicle Air Conditioning

ARB Climate Change Workshop
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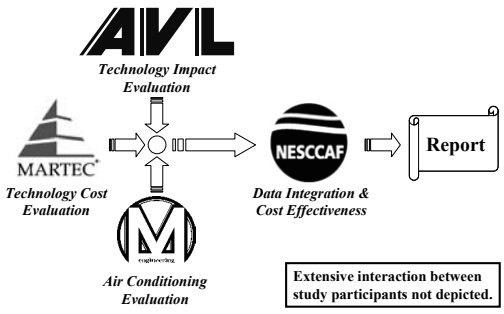


Extensive interaction between study participants not depicted.

Air Conditioning GHG Influences

- Direct emissions -- leakage of refrigerant.
- Indirect emissions -- increased tailpipe CO_2.
  - Increased CO_2 due to air conditioning (A/C) system mass (engine works harder to carry the weight). Impacts accrue whether the system is on or off.
  - Increased CO_2 due to the power demands of the A/C system (engine works harder to provide A/C operating power). Impacts accrue only when A/C is on.

Direct A/C Emissions

- NESCCAF report includes an analysis of direct A/C emissions.
- ARB has performed an independent analysis that will be presented separately today.
- This presentation focuses on indirect A/C GHG emissions.

Mass-Related A/C GHG Impacts

- GHG contribution due to A/C system mass is generally small relative to leakage and operating power impacts. But, can be significant in low A/C usage areas with reduced GWP refrigerants.

A/C System	Without Secondary Loop			With Secondary Loop		
	CO_2 Emission Rate (g/mi)	Lifetime CO_2 Emissions (kg)	Change from Current HFC-134a	CO_2 Emission Rate (g/mi)	Lifetime CO_2 Emissions (kg)	Change from Current HFC-134a
Current HFC134a	1.7	249.6	Base	not applicable		
Enhanced HFC-134a	1.5	226.9	-9.1%	not applicable		
HFC-152a	1.5	226.9	-9.1%	1.9	287.4	+15.2%
Propane (R-290)	1.5	226.9	-9.1%	1.9	287.4	+15.2%
CO_2 (R-744)	1.7	257.1	+3.0%	2.1	317.6	+27.3%

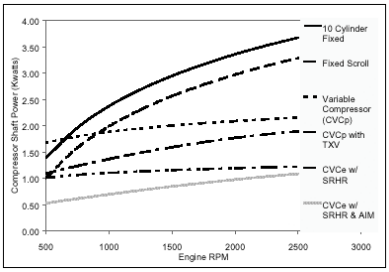
Indirect GHG Due to Power Demand

- A/C cooling demand (and thus power demand) varies with climate (geography).
  - There is no absolute impact that applies across all areas.
- NESCCAF looked at low, high, and average demand areas via spreadsheet analysis and average demand via CRUISE simulation analysis.
  - Demand analysis limited to U.S. conditions and based on meteorological and thermal comfort analysis by Rugh and Hovland at NREL.

Indirect GHG - Simulation Analysis

- Comprehensive results of NESCCAF A/C analysis (spreadsheet and simulation) are presented in the study report. However, in the interest of time, this presentation focuses on the CRUISE simulation analysis of A/C impacts.
- Simulation analysis investigated the indirect impacts of a baseline fixed displacement compressor (FDC) A/C system and the reduction benefits of a variable displacement compressor (VDC) system with advanced air management.

FDC versus VDC Power Demand



Power Demand Relative to a 215 cc FDC (Forrest, 2002-01-0229)

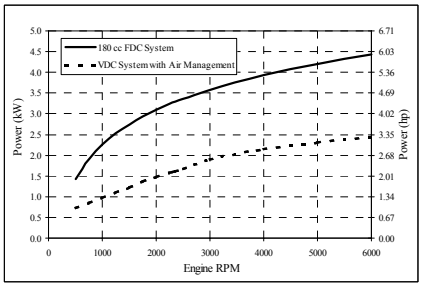
Adjustment of Forrest Data (1)

- Forrest (Delphi) data were adjusted to produce class specific power demand curves for a baseline HFC-134a FDC system and an alternative HFC-152a VDC system with advanced air management.
- Delphi reduced reheat benefits were excluded as primarily applicable to automatic climate control vehicles.
  - Both baseline and alternative A/C systems assumed to be manual control.
- All curves established for U.S. average A/C usage conditions.

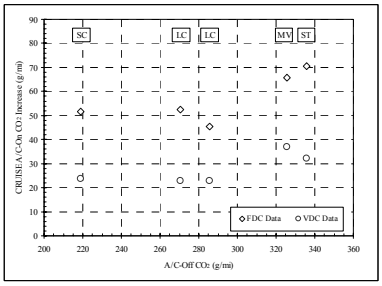
Adjustment of Forrest Data (2)

- Both FDC and VDC power demand curves were scaled to account for vehicle class-specific compressor sizes as follows:
  - 150 cc for small car.
  - 170 cc for large car.
  - 210 cc for all truck classes.
- 5 percent reduction was applied to VDC demand curve to simulate efficiency benefits of HFC-152a.
- AVL ran five simulations of FDC versus VDC impacts.

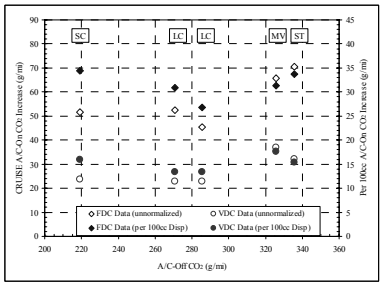
Example Power Demand Curves



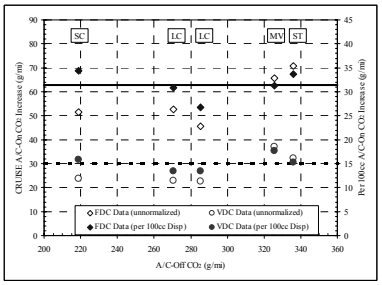
Simulation Modeling Results (1)



Simulation Modeling Results (2)



Simulation Modeling Results (3)



A/C Impact Summary

- The indirect CO_2 impacts of HFC-134a FDC system are estimated to be 31.4 g/mi/100 cc compressor displacement.
  - 10.7 g/mi/100 cc when adjusted for 34 percent A/C "on time."
- The indirect CO_2 impacts of HFC-152a VDC system are estimated to be 15.1 g/mi/100 cc compressor displacement.
  - 5.1 g/mi/100 cc when adjusted for 34 percent A/C "on time."
- The VDC system is estimated to reduce indirect A/C impacts by about 51 percent.

A/C Impact Example